systems, such as MLDS, are not so constrained. As a result, MLDS systems can be installed expeditiously, thereby providing faster service to the public. Swifter introduction of service vis-a-vis cable is also possible because MLDS systems can serve customers with relatively small capital investments.[31/] In addition, MLDS is compatible with any high definition television ("HDTV") standard and promises to allow for earlier introduction of HDTV than is likely to be possible with cable television.

MLDS also provides consumer benefits unmatched by other video distribution systems. For example, MLDS will not be burdened with the lower channel capacity[32/] or significantly higher start-up charges that hamper the ability of DBS and MMDS to compete with cable television. Similarly, the MLDS FM format and cellular configuration allow for a much higher quality grade of service, larger total coverage areas, and avoidance of the

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CEO of Continental Cablevision, Inc. at a seminar sponsored by the National Cable Television Association and National Association for Minorities in Cable, "Urban Markets: Directions for the '90s" (September 28, 1988).

31/ See F. Setzer, J. Levy, "Broadcast Television in a Multichannel Marketplace," OPP Working Paper #26 at 109 (June 1991).

32/ Currently, even under ideal circumstances, MMDS is limited to 31 channels compared to the minimum 48 channels available to MLDS. Indeed, in most markets, MMDS operations are unable to accumulate more than a handful of channels and many of those are typically only available after lengthy and expensive negotiations. See id. at 110. Moreover, unlike MLDS, MMDS will be unable to employ digital video compression techniques to expand such capacity because of its inadequate receiver technology and its problems with multipath, interference and shadowing.

line-of-sight propagation limitations that severely restrict MMDS' ability to serve large numbers of households.[33/] In addition, because of the MMDS AM modulation characteristics, unlike MLDS, its signal cannot be repeated and it has limited channel capacity. Furthermore, the frequencies on which MMDS operates allows for ghosting due to multipath propagation, low receiver antenna gain, and large beamwidth. And finally, unlike Satellite Master Antenna Television ("SMATV"), MLDS does not require the installation of costly satellite earth stations with a cable television headend at every building to be served, or a costly multiple point-to-point backbone system.[34/]

Moreover, to the extent that voice and/or data applications are implemented, MLDS licensees can also compete with local exchange carriers ("LECs"). As the Commission recently stated, such competition creates benefits for the public:

[33/] MMDS, with its long path lengths and line-of-sight propagation, suffers from multipath interference and path blockage problems which generally limit the number of potential subscribers to a small percentage of that served by cable. These problems are difficult to remedy with the AM system used by MMDS. MMDS cannot use multiple repeated cells at the same frequency, hence, that system is limited to only one transmitting node. In contrast, MLDS has short path lengths that are less likely to be blocked. In addition, as an FM system, MLDS can easily employ co-channel repeaters and a variety of interference-mitigation techniques to reach shadow areas. In addition, MMDS systems cannot be operated next to each other.

[34/] In addition, in large cities such earth stations are affected by terrestrial interference which is hard and expensive to overcome. Furthermore, a recent Rand Corporation study found that SMATV systems are unlikely to become a widespread threat to cable television because such systems have been "bought out" by cable operators. See Duggan Speech note 25 supra.

> subject[ing] LEC operations more directly to the discipline of greater competition ... should lower the price of services subject to competition, and, in the long term, increase the overall efficiency of LEC operations. It should also provide a competitive spur for the LECs to deploy new technologies and improve service quality ... [It] should also increase customer choice ... [by providing] a greater selection of services meeting more rigid technical specifications or more stringent installation and maintenance intervals. Increased competition also should enhance customer choices in establishing redundant facilities for network reliability.[35]

Where such competition or "bypass" of the LEC's technologies have been offered, they have met the policy goals of creating benefits for the public. For example, a recent six city survey conducted by Quality Strategies, Inc. has shown that, in areas such as price, responsiveness, and network performance, alternative access providers provide better T1 service to corporate customers than local telephone companies.[36]

In addition, MLDS may provide services that the LECs cannot. For example, MLDS licensees can offer two-way voice and data links customized to the traffic pattern in their individual coverage area. In principal, such services can also be offered by LECs, but such an array of different services awaits the arrival of ISDN and digital local loops for economic offering to the public; this is unlikely to occur for another ten years.[37]

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[35] Expanded Interconnection with Local Telephone Company Facilities, Notice of Proposed Rulemaking and Notice of Inquiry, 6 FCC Rcd 3259, 3261, ¶¶ 13-14 (1991).

[37] See K. Killette, "Study: Bypass Service Better," Communications Week at 30 (July 15, 1991).

[37] Sarnoff Report at Section III, "Secondary Services."

As a result of these advantages, potential MLDS licensees are exhibiting intense interest in providing MLDS. Within the past nine months alone, at least 32 applications have been filed to waive Part 21 to offer MLDS or MLDS-like services.[38/]

Rather than dealing with these requests on an ad hoc waiver basis, however, the Commission would better serve the public interest by initiating a rulemaking to explore the best use of the 28 GHz spectrum.[39/] "[U]tilizing rulemaking procedures opens

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38/ See, e.g., LDH International, File No. 10797-CF-P-91 (appeared on Public Notice May 15, 1991); Evanston Transmission Company, File No. 12268-CF-P-91 (appeared on Public Notice June 26, 1991); Cellular Vision, Inc., File No. 122775-CF-P-91 (appeared on Public Notice August 21, 1991) These applications are based, in large part, on the Part 21 waivers that the Commission granted in the Hye Crest Order.

Other 28 GHz activity also indicates that a change of Part 21 is needed. See Harris Corporation -- Farinon Division, Petition for Rulemaking (seeking to allow Part 94 private microwave carriers to use the 28 GHz band and adoption of a channelization plan for that band), RM-7722 (filed on April 19, 1991; FCC Public Notice released on May 16, 1991). It does not appear possible for the Commission to accommodate all of the proposals contained in the Suite 12 and Harris Petitions. Suite 12 has recommended that the Commission dismiss the Harris Petition because it does not adequately advance the public interest. See Suite 12 Opposition to the Harris Petition (filed with the FCC June 14, 1991). Indeed, five of the six parties that commented on the Harris Petition opposed it or advocated that it be dismissed.

39/ See, e.g., Lee Optical, Memorandum Opinion and Order, 57 RR 2d 1296, 1298, ¶ 6 (1985); Resolution of Interference between UHF Channels 14 and 69 and Adjacent-Channel Land Mobile Operations, Notice of Proposed Rulemaking/Notice of Inquiry, 2 FCC Rcd. 7328, 7335, n. 21 (1987).

Although in the Hye Crest proceeding Suite 12 successfully argued against initiating a rulemaking proceeding, Suite 12 has reexamined its position and, in light of the heightened interest in this spectrum, it now believes that the FCC must pursue a

(footnote continued)

up the process of agency policy innovation to a broad range of criticism, advice and data . . . ."[40/] A rulemaking will permit the Commission to perform a comprehensive analysis of the best use of the 28 GHz spectrum in a methodical and deliberate fashion. Suite 12 proposes that MLDS constitutes the best use of this spectrum.

V. THE COMMISSION SHOULD ADOPT THE LICENSING AND TECHNICAL REQUIREMENTS NECESSARY TO ENSURE THAT MLDS CAN BECOME A VIABLE SERVICE

In the event that the Commission initiates a rulemaking to establish MLDS, it should propose MLDS rules that are sufficiently flexible to allow MLDS to become an economically and technically viable service. Although Suite 12's proposed rules are detailed in Appendix A, the proposals that Suite 12 believes are particularly essential are highlighted below.

To the best of Suite 12's knowledge, MLDS is the first wireless telecommunications service whose technology is designed to offer not only video distribution but two-way voice, video and data applications as well. Given this unique capability, the

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rulemaking. A reallocation of spectrum and the adoption of rules targeted specifically to MLDS will afford this service the necessary structure to become an economically viable service that can be offered on a wide-spread basis.

40/ Nat'l Petroleum Refiners Assoc. v. FTC, 482 F.2d 672, 683 (D.C. Cir. 1973); see also Industrial Broadcasting Co. v. FCC, 437 F.2d 680, 683 (D.C. Cir. 1970); Amendment of Section 22.501(a) of the Rules to allow One Way Signaling on the 35 MHz Frequency Band, Memorandum Opinion and Order and Notice of Proposed Rulemaking, 78 FCC 2d 438, 439 (1980), aff'd sub. nom. Mobile Telecommunications Corp., Mimeo No. 29577 (rel. July 14, 1981).

Commission's rules should permit MLDS licensees to offer these services as the marketplace, rather than the federal government, dictates.[41/] In this fashion, the Commission will encourage MLDS licensees to provide innovative service offerings that can respond to the localized needs of the subscribers in their service area. In addition, because there is virtually no point-to-point use of the 28 GHz band,[42/] it is unlikely that such regulatory flexibility will foreclose other uses of the band or otherwise harm the public.

A. All Entities Should Be Eligible To Become MLDS Licensees

Suite 12 favors the most expansive eligibility criteria feasible for MLDS licenses.[43/] Any entity should be eligible to become a MLDS licensee, provided that it is legally, technically, and financially qualified to operate MLDS facilities and the spectrum is available for it to render MLDS service. The more diverse the pool of MLDS licensees, the greater the likelihood that the public will benefit from competition, innovation, and diverse programming.

41/ However an MLDS licensee configures its service package, it should employ a system design that enables the delivery of at least 48 video channels throughout its designated service area. See Proposed Rule Section 21.1011, Appendix A. As a consequence of this configuration, it is unlikely that there will be "pure" voice or data MLDS offerings; however, novel combinations of (1) video and voice, (2) video and data, or (3) video, voice, and data applications will no doubt evolve. See Sarnoff Report, Section III, "Secondary Services."

42/ See Section III supra.

43/ See Proposed Rule Section 21.1000, Appendix A.

Although their entry into the MLDS market may present some difficulties, Suite 12 favors allowing telephone companies and cable operators to become MLDS licensees.[44/] These entities can bring valuable technical and marketing expertise, as well as considerable financial resources, to the provision of MLDS. Such capabilities will help ensure that the benefits of MLDS become available to the public in a rapid and efficient manner.

B. The Commission Should Award Only Two MLDS Licenses Per Market

MLDS' ability to immediately compete with cable television, one of the principal benefits of MLDS, will be lost if the Commission does not allocate enough spectrum for each MLDS licensee.[45/]

[44/] To the extent that video MLDS is viewed as an alternative vehicle for cable television, the telephone companies may be prohibited under the Cable Act from owning or operating MLDS facilities in their service area. Similarly, to the extent that MLDS voice or data applications require interconnection to telephone company facilities, the Commission may feel compelled to impose safeguards against potential anticompetitive behavior by these companies as a condition for their entry into the MLDS market. See e.g., Second Computer Inquiry, Docket No. 20828; Third Computer Inquiry, CC Docket No. 85-229.

While cable operators are not prohibited by federal law or regulation from providing two-way local communications services, they may be so constrained by state regulatory barriers. The Commission may wish to consider the preemption of such constraints if they interfere with the Commission's policy goals.

[45/] Twice in recent years, the Commission has made the mistake of creating new services and then awarded inadequate capacity for new licensees to compete with entrenched operators. Rather than repeat these mistakes the Commission should award MLDS licensees with sufficient spectrum to offer a viable service. First, in creating the Digital Electronic Message Service ("DEMS"), the Commission channelized the 10.55-10.68 GHz band to support as many

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With currently available technology, such channel capacity is available only if the Commission awards no more than two MLDS licenses per market, with each licensee receiving 1000 MHz of spectrum.[46/] While such capacity is virtually unheard of in lower frequency bands, 1000 MHz in the 28 GHz band represents only 3.5 percent of the available spectrum; in contrast, television and MMDS utilize 62 percent and 7.4 percent respectively of the available spectrum. Moreover, such capacity is necessary for MLDS to be cable's technical equal.

It is conceivable that, someday, Quanternary Phase Shift Keying ("QPSK") or other spectrally efficient technologies will evolve to permit additional channel capacity and greater service. This technology upgrade will be equally applicable to cable, fiber

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as 16 competitors per city. Amendment of Parts 2, 21, 87, and 90 of the Commission's Rules to Allocate Spectrum for, and to Establish Other Rules and Policies Pertaining to, the Use of Radio in Digital Termination Systems for the Provision of Digital Communications Services, Report and Order, 86 FCC 2d 360 (1981). DEMS was a common carrier digital telecommunications network that could provide high-speed, end-to-end, two way transmissions of digitally encoded information. As a consequence of having insufficient spectrum to compete with the telephone company, DEMS never developed into a viable service.

Similarly, in creating MMDS, the Commission prohibited a single entity from licensing all eight MMDS channels in a city. Although, in recent years, the Commission has attempted to provide MMDS with additional channel capacity, MMDS has not evolved to its potential because of these bandwidth limitations.

46/ See Proposed Rule Section 21.1001, Appendix A. Given that the 28 GHz band contains 2000 MHz of spectrum and assuming each MLDS channel has a bandwidth of 18 MHz each, in order to provide each licensee with at least 48 video channels, there can only be two licensees.

and MLDS without the need for additional spectrum.[47] Two licensees should be sufficient to ensure a competitive environment. The introduction of two MLDS licensees to each market will inject two new entrants, each of whom will not only compete with each other, but with the entrenched monopoly cable provider. As a consequence, the FCC will ensure that the public has a choice of at least three providers for multichannel video service; such competition will permit market forces, rather than regulation, to ensure low prices and sector-specific program diversity.

C. Common Carrier Regulations Should Not Apply To MLDS Licensees

The Commission should decline to impose common carrier regulatory status on MLDS licensees.[48] Pursuant to the NARUC decision,[49] such non-common carrier status is appropriate here because there is no inherent legal compulsion that MLDS licensees hold themselves out to serve the public indiscriminately.[50]

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[47] Since both the wireless and wired systems begin with the same basic service parameters, any expansion of service by improvements in technology is equally applicable to both systems. This should speed the implementation of technology for improvement in quantity and quality of service as well as lower cost. New innovative services can utilize either system.

[48] See Proposed Rule Section 21.100, Appendix A.

[49] See NARUC v. FCC, 525 F.2d 630, (D.C. Cir. 1976), cert. denied, 425 U.S. 992 (1976) ("NARUC").

[50] See id. at 640-43. It is fully expected that MLDS licensees will "make individualized decisions, in particular cases, where and on what terms to deal." Id. at 641. As such, they cannot be considered to be common carriers. See id.

Moreover, as the Commission determined when it conferred non-common carrier status on Hye Crest: (1) MLDS would be only one of several video services available to consumers in any particular market; (2) MLDS licensees would not hold themselves out as serving all customers indiscriminately; and, (3) there would be no public interest need for MLDS licensees to comply with the obligations attendant to common carrier operation.[51/] Non-common carrier status for MLDS is also beneficial because it will enable licensees to use some or all of their transmission time and transmission capacity for their own purposes, including controlling the content of their services, if they so desire. This ability will encourage the development of localized programming.[52/]

D. A Channelization Plan Should Not Be Adopted for MLDS

Rather than adopting a specific channelization plan, the Commission should award each MLDS licensee a block of spectrum and allow the licensee to subchannelize it in any manner that satisfies the licensee's marketing, technical, and engineering needs with a minimum of 48 video channels.[53/] The resulting

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[52/] See Hye Crest Order, 6 FCC Rcd at 335, ¶ 26. See also Revisions to Part 21 of the Commission's Rules Regarding Multipoint Distribution Services, Report and Order, 2 FCC Rcd 4251 (1987).

[52/] See Section IV supra.

[53/] See Proposed Rule Section 21.1001, Appendix A. The Commission's decision regarding channelization in the satellite area is precedent for this type of approach. See Amendment of Parts 2 and 22 of the Commission's Rules Relative to Cellular

(footnote continued)

flexibility will allow MLDS to evolve in a market-oriented and innovative fashion.

E. MLDS Frequencies Should Be Granted On A Designated Service Area Basis Confined To A Primary Metropolitan Statistical Area

Suite 12 proposes that the Commission adopt a designated service area approach to provide each MLDS licensee with the freedom to select multiple transmitter sites within the boundaries of a Primary Metropolitan Statistical Area ("PMSA").[54/] As the Commission has previously stated, "[i]n view of the [short] propagation characteristics of the 28 GHz band, only a designated service area licensing scheme will provide the licensee with the necessary flexibility to select and timely establish antenna locations to facilitate efficient frequency re-use, and, thereby assure continuous signal coverage."[55/]

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Communications Systems, Report and Order, 61 RR 2nd 165 (1986), recon. den., 62 RR 2nd 1329 (1987), recon. den., 66 RR 2nd 1351 (1989), aff'd sub nom. Aeronautical Radio Inc. v. FCC, 68 RR 2nd 1387 (1991); Amendments of Parts 2, 22, and 25 of the Commission's Rules to Allocate Spectrum for, and to Establish Other Rules and Policies Pertaining to the Use of Radio Frequencies in a Land Mobile Satellite Service for the Provision of Various Common Carrier Services, Second Report and Order (to consider twelve Mobile Satellite Applications), 62 RR 2nd 48 (1986), clarified, 62 RR 2nd (1987), recon. den., 66 RR 2nd 1365 (1989).

54/ See 47 CFR § 21.500 and Proposed Rule Section 21.1002, Appendix A.

55/ Hye Crest Order, 6 FCC Rcd at 335, ¶ 27. This designated service area licensing scheme is also consistent with that allowed for DEMS and the Cellular Radio Telecommunications Service. See Revision of Part 21 of the Commission's Rules, Report and Order, 2 FCC Rcd. 5713 (1987), recon. granted in part, (footnote continued)

Without a designated service area approach, MLDS licensees will not be able to compete with other multichannel video distribution providers that serve entire metropolitan areas. Disjointed coverage, gaps in available channel capacity, and/or impaired signal strength would unnecessarily diminish the marketability of this new competitive service and severely impede its ability to compete against the entrenched and predominant presence of cable television in the market.

F. The Commission Should Award Blanket MLDS Licenses

Rather than requiring a MLDS licensee to seek a separate license for each cell site in the PMSA, the Commission should issue blanket licenses to cover the entire designated service area. In this fashion, the MLDS licensee will have the flexibility to engineer its system and locate its cell sites to take advantage of optimal millimeter wave propagation features. In addition, this process is administratively streamlined, it will conserve FCC resources, and it will permit prompt, efficient service delivery to the designated area.

In contrast, licensing the cells individually will result in a patchwork quilt of system design that would greatly diminish the feasibility of frequency reuse and operational compatibility. Moreover, each additional transmitter site would be subject to a

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65 RR 2nd 1849 (1989); An Inquiry into the Use of the Bands 825 - 845 MHz and 870 - 890 MHz for Cellular Communications Systems, Report and Order, 49 RR 2nd 809, 836, ¶ 87, appeal dismissed, Case No. 82-1526 (D.C. Cir. 1983).

full thirty day public notice period and thus to competing applications. Licensing each cell individually would serve no purpose but to introduce delay and unreasonably burden the Commission's administrative process; it would offer no countervailing benefits to the public.

To avoid these difficulties and to provide MLDS licensees with adequate flexibility to implement a consistent and efficient system design, Suite 12 proposes that the Commission apply the notification procedures described in 47 CFR Section 21.711 of its current rules for licensing each transmitter beyond the initial one.[56/] That rule section permits the licensee to notify the Commission's Engineer in Charge of the radio district of any new operation rather than seeking an individual license for each transmitter site within the PMSA.[57/]

56/ See Proposed Rule Section 21.1002, Appendix A.

57/ Alternatively, if the Commission is disposed to treat additional transmitter sites within the designated area as minor facility modifications, the approach of 47 CFR Section 21.41 may be appropriate. Under this approach, licensees for individual transmitter sites would be automatically granted on the twenty-first day following the date of the public notice.

G. The Commission Should Adopt Frequency Modulation As the Benchmark for Spectral Efficiency

While the Commission may choose to allow MLDS licensees to use other technical approaches, an FM network design, using 18 MHz per video channel, should be treated as a benchmark for spectral efficiency.[58/] MLDS applicants wishing to use some other technical approach (for example, QPSK or QAM) should be required to show that they can achieve at least the same capacity as an FM system based on at least 48 video channels at 18 MHz per channel, with the same frequencies being used at adjacent cell sites.[59/] Polarization reversal in both adjacent cells and shadow areas should be implemented to allow for non-interference performance, repeatability of signal, and maximum service capability. As is demonstrated in the attached Sarnoff Report, FM modulation is extremely spectrally efficient and should be utilized by MLDS licensees.

58/ See Proposed Rule Section 21.1006, Appendix A.

59/ It is unlikely that AM technology can achieve the same high level of spectral efficiency, because of the extreme power requirement, high intermodulation distortion, inability to reach shadow areas and inability to reuse the same frequencies in adjacent cells. See Sarnoff Report at 78-81.

VI. CONCLUSION

Suite 12 respectfully requests that the Commission initiate a rulemaking to reallocate the 28 GHz spectrum to MLDS and to license such systems pursuant to the rules proposed herein. Such a reallocation will be in the public interest because it will permit the establishment of competition to cable television and other services and it will permit currently fallow spectrum to be used.

Respectfully submitted,

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Section I

SYSTEM PERFORMANCE PARAMETERS

1. Introduction

The purpose of this report is to technically review the Suite 12 millimeter wave multi-channel distribution system and suggest methods for optimizing the use of the 27.5 to 29.5 GHz frequency spectrum in its application to video distribution and two-way interactive services (i.e., telephone, video phone, and data).

The first section of the report analyzes the transmission and propagation characteristics of 28 GHz communication systems and the various modulation methods which can be used to provide the best attainable system performance with realizable and cost effective components.

The second section describes the Suite 12 system, along with details on the frequency plan, transmitter and receiver components based upon the technical analysis of the first section.

2. Link Equations for Determining Effective Radiated Power (ERP)

A basic communication system consists of a transmitter and receiver. The most important criteria in establishing the viability of a communication system is to establish the necessary relationships between the transmitter power, receiver noise figure, distance between transmitter and receiving sites, and other factors effecting the path loss between transmitter and receiver.

The following notations will be used.

ERP/carrier = Effective radiated power (dBW), per video carrier

ERP(total) = Total ERP required from the transmitting system for n video carriers, dBW

n = Number of video carriers

D	=	Distance between the transmitter and receiver, miles. This is the cell radius.
L	=	Free-space loss over a distance D, at frequency f (MHz)
	=	36.58 + 20 log(f) + 20 log D, dB
A	=	Attenuation due to rain over a distance D miles, corresponding to a specified availability
G_r	=	Receiver antenna gain, dBi. For parabolic dish with 55% efficiency this equals 20 log f(MHz) + 20 log d - 52.6, dBi, where d is the dish diameter in feet
NF	=	Receiver noise figure, dB
T	=	Receiver noise temperature, ,°K, $300\ (10^{0.1NF} - 1.0)$
k	=	Boltzmann's constant, -228.6 dB
B	=	Noise bandwidth of the carrier, MHz
R	=	Rain rate corresponding to a specified availability requirement, mm/hr
C	=	Video carrier power at the receiver antenna output, dBW
CNR	=	Carrier-to-noise ratio (dB), in bandwidth B

Then

$$C = (ERP/carrier) - L - A + G_r, dBW$$

$$CNR = C - k - (10 \log B + 60.0) - 10 \log T, dB$$

The value of ERP/carrier can then be determined using the equation

$$(ERP/carrier) = CNR + L + A - G_r + k + (10 \log B + 60.0) + 10 \log T, dBW$$

which relates the required carrier-to-noise ratio of the system, the path loss between transmitter and receiver, the noise characteristics of the receiver, and the effective radiated power of the transmitter.

3. Rain Attenuation

Examination of the previous equation for the required effective radiated power indicates a single parameter which is not controlled by the system designer, the attenuation due to rain (A). To achieve reliable communications, this factor must be taken into account so that the controllable system parameters (e.g. ERP, receiver noise figure, antenna gain) can be specified to compensate for its deleterious effects.

Rain attenuation prediction models are discussed in detail in Appendix A-1. The attenuation due to rain is shown to be a function of the rain rate in mm/hour for a specified availability requirement.

In this study we selected New York and Los Angeles as cities with high population density and where wireless cable TV distribution has a significant opportunity for deployment. For rain availability, a service level of 99.9% at the circumference (fringe) of the cell in an average year was chosen. This is somewhat better than the typical DBS specifications of 99% availability in the worst month of an average year (WARC '77). In addition, a worst case situation was assumed in which the maximum rainfall intensity was homogeneous throughout the cell. In reality, rainfall over a large area is not uniform and the maximum intensity is usually limited to a diameter of less than one mile.

Attenuation values for various availabilities and distances for different regions of the U. S. can be found in the appendix along with rain rate contours. This data will be used for link calculations in latter sections.

4. CNR and SNR Requirements for Modulation Candidates

The signal-to-noise ratio (SNR) of the baseband signal is a measure of the quality of the signal. In video transmissions, a viewer will judge a picture with a high SNR of higher quality than one which has a lower SNR. A result of several studies indicate that viewers will judge a picture which has a SNR of 55 dB to be "excellent" and 90% of the viewers would rate a picture with a SNR of 42 dB to be "fine".

The carrier-to-noise ratio (CNR) is related to the SNR, but the relationship is dependent on the type of modulation used. The following discussion will show that FM systems are capable of providing higher SNR's than AM systems for the same CNR. This is important because as the link equation shows, the effective radiated power requirement is directly proportional to the CNR. Therefore, an FM system will require less power for the same picture quality. A discussion of digital modulation is included because it is an emerging technology with possible future applications in the Suite 12 system.

We will determine the ERP required per video carrier for three differenttypes of modulation:

FM channels of different bandwidth

AM channels of 6 MHz bandwidth

Digital transmissions of different types

FM Channels: For FM and AM carriers, the performance is determined through the baseband signal-to-noise ratio values:

SNR = CNR + VRTF, dB

where VRTF is the Video receiver transfer function. For FM links with noise bandwidth B (MHz), and NTSC baseband,

$$VRTF = 6(F_d/4.2)^2 (B/4.2)\, p$$

where

F_d = Peak FM deviation

p = De-emphasis and unified noise weighting factor

= 12.9 dB

For FM transmission three bandwidth values are considered here 36, 24, and 18 MHz. The corresponding allocated bandwidths are 40, 27, and 20 MHz, respectively.

The bandwidth of 40 MHz corresponds to (primarily) C-band satellite FM transmission, in which the FM carrier has a bandwidth of 36 MHz. The bandwidth of 27 MHz was chosen because this is the nominal bandwidth of a DBS transponder, and also the FM bandwidth of Ku-band FSS links for direct-to-home service. The bandwidth of 20 MHz was chosen to examine the results for a narrowband FM which is commonly considered and used as a "half-transponder" bandwidth.

Given the FM bandwidth B, the peak deviation F_d can be determined using the Carson's rule

$$F_d = (B/2) - 4.2 \text{ MHz}$$

If B = 36 MHz (C-band transmission), the FM deviation can be set to the Carson's value 13.8 MHz, but historically satellite operators set the value to 10.7 MHz, to allow additional deviation by audio subcarriers. However, this is not necessary, and excellent reception is possible, if F_d is set to 13.2 MHz, even in the presence of audio subcarriers. In spite of this, we will set F_d to 10.7 MHz, since a large number of FM receivers are set to this value. When B = 24 and 18 MHz, the deviation can be set to values larger than the Carson's values 7.8 and 4.8 MHz, respectively, since the reception is directly to home (instead of a cable headend). It is common to use 10% overdeviation, which yields the values 8.58 and 5.28 MHz, respectively. Based on these observations, the following deviations are selected:

$$F_d = \begin{cases} 10.7 \text{ MHz}, & \text{if } B = 36 \text{ MHz} \\ 8.6 \text{ MHz}, & \text{if } B = 24 \text{ MHz} \\ 5.3 \text{ MHz}, & \text{if } B = 18 \text{ MHz} \end{cases}$$

Hence the values of VRTF can be computed, and are given by

$$\text{VRTF} = \begin{cases} 38.13 \text{ dB}, & \text{if } B = 36 \text{ MHz} \\ 34.47 \text{ dB}, & \text{if } B = 24 \text{ MHz} \\ 29.02 \text{ dB}, & \text{if } B = 18 \text{ MHz} \end{cases}$$

We will next consider the SNR (weighted) value required for reasonable service quality in rain faded condition. Figure I-4.1 shows the SNR required for various quality levels on the CCIR 5-point impairment scale (Report 634-3, 1986, Fig. 23):

5 = Imperceptible Impairment

If B = 36 MHz (C-band transmission), the FM deviation can be set to the Carson's value 13.8 MHz, but historically satellite operators set the value to 10.7 MHz, to allow additional deviation by audio subcarriers. However, this is not necessary, and excellent reception is possible, if F_d is set to 13.2 MHz, even in the presence of audio subcarriers. In spite of this, we will set F_d to 10.7 MHz, since a large number of FM receivers are set to this value. When B = 24 and 18 MHz, the deviation can be set to values larger than the Carson's values 7.8 and 4.8 MHz, respectively, since the reception is directly to home (instead of a cable headend). It is common to use 10% overdeviation, which yields the values 8.58 and 5.28 MHz, respectively. Based on these observations, the following deviations are selected:

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We will next consider the SNR (weighted) value required for reasonable service quality in rain faded condition. Figure I-4.1 shows the SNR required for various quality levels on the CCIR 5-point impairment scale (Report 634-3, 1986, Fig. 23):

5 = Imperceptible Impairment

4 = Perceptible, but not annoying

3 = Slightly annoying

2 = Annoying

1 = Very annoying

The solid line shown in Figure I-4.1 can be fitted by the function

$$Q = (SNR/6) - 22/6$$

where SNR is in dB. Selected values of SNR and Q are as follows:

SNR (dB)	Quality
40.0	3.0
41.0	3.2
42.0	3.3
43.0	3.5
44.0	3.7
45.0	3.8
46.0	4.0
52.0	5.0

Based on this, we can choose the faded performance SNR at the fringe of a cell criterion to be 42.0 dB, minimum (a non-faded performance of SNR=55 dB or Quality grade 5 is expected). Hence the required CNR should be

$$CNR > 42.0 - VRTF, dB$$

It is also required that CNR be at least 8 dB (see Figure I-4.2) for above-FM threshold operation. If the above inequality becomes a strict equality, the lowest required ERP/carrier can be determined.

AM Channels: For AM links (B = 6 MHz) the quality can be assessed by setting VRTF to 0.0 dB, in which case the SNR is said to be the TASO[1] value:

$$SNR(TASO) = CNR \text{ in } 6.0 \text{ MHz}$$

For AM links we will determine the minimum SNR required from TASO test results. The picture quality grades used in the TASO study are

SNR-dB	
55	Excellent
42	Fine
34	Passable
28	Marginal
21	Inferior

The relationship among quality, SNR and percent of viewers rating picture as of stated quality or better, are shown in Figure I-4.3(a). Based on this we can choose an SNR(TASO) value of 42 dB as the goal under faded condition. At this SNR, 90% of viewers would rate the picture (Figure I-4.3(b)) as "fine", or better. A 55 dB ratio is considered to be "excellent" and greater than the quality received at cable head ends.

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[1] Television Allocation Study Organization (TASO), "Engineering Aspects of TV Allocation," Report to the FCC, March, 1959.

Digital Channels: For digital carriers, the CNR value can be used to determine the bit error rate (BER), and consequently the link performance level. This depends on the type of data modulation used for compressed video transmission. A number of possibilities exist, and they are discussed below.

a) Channel bandwidth per video carrier (B) is 6 MHz, and the modulation method corresponds to the terrestrial digital HDTV standard. The channel spacing is also 6 MHz. The modulation will be a variation of 16 or 64 level QAM. Since the standard is expected to perform satisfactorily on the FCC Grade B (NTSC) contours of terrestrial transmission coverage, we can assume that the CNR required in 6 MHz is the same as that which is realizable on the Grade B contour. With FCC planning factors, the CNR value is 28 to 29 B. Hence we can assume here that the rain faded CNR requirement is 30 dB, in 6 MHz. (Even though NTSC performance at CNR of 30 dB is not good, digital channels are expected to be of good quality.) This method of transmission will be designated as "Digital HDTV". Clearly, such a channel will be compatible with HDTV consumer receivers. The data rate in the channel will be in the range of 21 to 23 Mbps.

b) In satellite transmission Quaternary Phase Shift Keying (QPSK) is a robust modulation, which is expected to be used in compressed digital video delivery applications. A QPSK channel with 36 and 24 MHz bandwidth can deliver 60 and 40 Mbps of high quality data. Such a link can be used to deliver four to eight good to excellent quality video channels. Systems of this type have been demonstrated by several companies (General Instruments, Scientific Atlanta, Compression Labs, and Skypix). The receiver equipment is expensive and represents an additional commong cost factor for both wireless and cable TV. We will now examine the feasibility of transmitting a QPSK digital carrier in 27 MHz bandwidth, in which the carrier occupies 24 MHz. The CNR requirement, in 24